A demonstration of the potential of Cryosat-2 to contribute to mesoscale observation

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1 – Abstract

Although the primary objective of ESA's Cryosat-2 is cryosphere science, the altimetry payload is operated globally on ocean.

This work illustrates that Cryosat-2 could be an asset for high-resolution (multi-mission) mesoscale observation.

While its orbit and payload are not ideal for oceanography, Cryosat can still capture 50% to 66% of the mesoscale variability observed with ENVISAT or Jason-1 in the Gulf Stream in near real time.

Cryosat-2 has the potential to mitigate the loss of old altimeters on operational NRT applications.

Reference: http://dx.doi.org/10.1016/j.asr.2011.07.002

2 – Methodology

Data used:

- 30 days of Cryosat-2 data generated by the Cryosat-2 Processing Prototype (CPP) from CNES (20 Hz, GDR-like)
- LRM mode only (no doppler/SAR data used)
- DUACS along-track SLA for Jason-2, Jason-1, and ENVISAT
- Period used: late October to late November 2010

Data preprocessing:

- Update of ancillary corrections (e.g. tropo, tides…)
- 20 Hz validation, filtering and compression to 1 Hz
- Global Cal/Val editing
- Crosscalibration with Jason-2 as a reference (standard DUACS processor, ENVISAT used as a model for parameters)
- Generation of along-track sea level anomalies (vs gridded MSS CLS/CNES 2011)

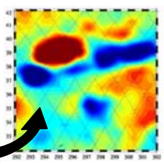
Processing and analyses:

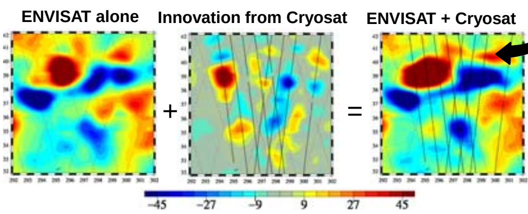
- Generation of multi-mission maps of SLA (from 1 to 4 satellites, with / without Cryosat)
- Comparison between maps with Cryosat and independent along-track measurements from the Jason tandem
- Comparison between configurations (1 to 4 sensors)
- Comparison to SST and OC

What/Where is the mesoscale content from Cryosat ?

3a – Qualitative improvements

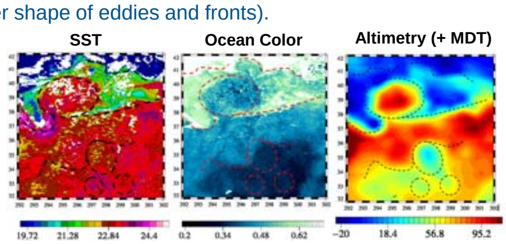
Adding Cryosat to ENVISAT maps substantially changes the shape and intensity of mesoscale features in the Gulf Stream (F1). Cryosat improves the consistency with independent maps from the Jason tandem.





F1 : Maps of sea level anomaly on 22/11/2010 and improvements from using Cryosat-2. Unit: cm.

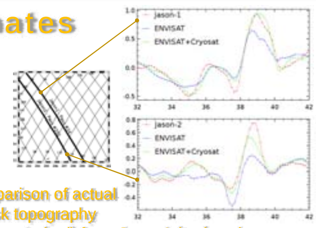
Comparisons between absolute topography from Cryosat + ENVISAT and SST or Ocean Color confirm (F2) that the contribution from Cryosat is beneficial (e.g. better shape of eddies and fronts).



F2 : Comparison of SST and chlorophyll concentration composite maps with the map of absolute dynamic topography built from ENVISAT and Cryosat-2. All maps are computed on 22/11/2010.
Units : °C, mg/m³, cm.

3b – Quantitative estimates

We interpolated ENVISAT and ENVISAT+ Cryosat maps on Jason tracks. From actual along-track measurements (IGDR) from Jason-2 and Jason-1, i.e. an independent truth, we can infer (F3) the benefits of using Cryosat (better consistency, i.e. reduction of difference RMS).



F3 : Comparison of actual along-track topography measurements (red) from Jason1 (top) and Jason2 (bottom) with interpolated maps from ENVISAT alone (blue) and ENVISAT + Cryosat (green). Unit: m.

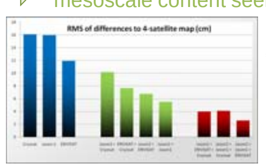
On average (F4) in the Gulf Stream, adding Cryosat yields a 7 cm RMS improvement, i.e. about 25% of the regional mesoscale variability.

Mission	Cycle	Pass	Age (in Map)	ENVISAT	ENVISAT + Cryosat	RMS of improvement (m)
				Difference between interpolated map values and actual measurements (m)		
Jason1	326	176	9	0.13	0.09	0.09
Jason1	326	202	8	0.14	0.13	0.04
Jason1	326	217	7	0.18	0.15	0.11
Jason1	326	252	6	0.06	0.05	0.02
Jason1	327	13	5	0.11	0.11	0.03
Jason1	327	24	5	0.15	0.08	0.12
Jason1	327	39	4	0.08	0.07	0.05
Jason1	327	100	2	0.12	0.09	0.08
Jason2	87	39	9	0.18	0.13	0.12
Jason2	87	100	7	0.08	0.06	0.05
Jason2	87	115	6	0.10	0.10	0.02
Jason2	87	191	3	0.06	0.06	0.01
Jason2	87	202	3	0.17	0.07	0.15
Jason2	87	217	2	0.06	0.05	0.03
			Avg	0.12	0.09	0.07

F4: Along-track differences between actual measurements from the Jason tandem, and interpolated values of ENVISAT maps and ENVISAT+Cryosat-2 maps. Column #7 gives the RMS of the improvement observed from using Cryosat-2 measurements. Unit: m.

The 4-sensor map is the best topography estimate in near real time. From differences to this reference, we can infer (F5) the improvement (reduction of difference RMS) from each satellite in constellations with 2 or 3 sensors.

Cryosat can capture about 50 to 66% of the mesoscale content seen by Jason or ENVISAT



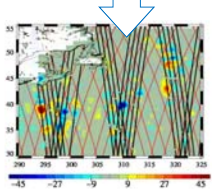
F5 : RMS of the differences between the "optimal" Near Real Time maps computed with 4 altimeters, and Near Real Time maps built from 1 to 3 satellites. Unit: cm.

4a – Limitation: sampling

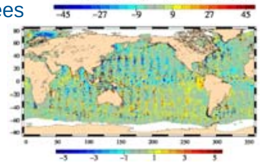
Cryosat's orbit is geodetic (one year repeat cycle) with a 30-day sub-cycle (global homogeneous sampling), but no sub-cycle in the 7 – 15 day range. The resulting NRT sampling is extremely irregular (F6) if one wants to observe mesoscale (decorrelation in ~15 days).

F6 : Typical 15-day sampling from Cryosat-2

As a result, the innovative content brought by Cryosat into multi-satellite NRT maps (F7) is located in 500 km wide bands alternating with 500 km wide "blind spots". The bands propagate westwards (~50 km / day).

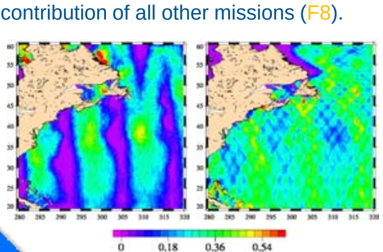


To infer the local (in each grid point) contribution of Cryosat in a 4-sensor map, we performed a degrees of freedom of signal analysis in the mapping OI.



While Cryosat's contribution is 20% in average, the DFS analysis confirms that it is primarily located in these 500 km bands, which largely contrasts with the spatially homogeneous contribution of all other missions (F8).

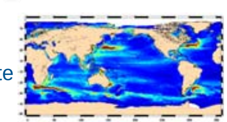
F7 : Difference in cm between a sea level map built from with Cryosat-2 and a map built without it computed on 22/11/10. Non-zero differences are aggregated near recent Cryosat measurements (black lines). Unit : cm.



F8 : Fraction of the 4-satellite map that is locally derived from Cryosat-2 (left) and Jason2 (right). Computed from a Degrees of Freedom Analysis (DFS) performed at each grid point (0.5 = 50%).

4b – Limitation: error budget

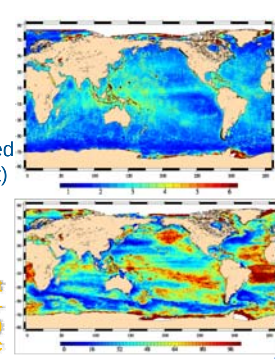
Cryosat's orbit and payload were designed for Cryosphere observation. This significantly increases Cryosat's error budget on ocean despite the very good behavior of SIRAL and DORIS.



F9 : Map of the mesoscale variability observed from DUACS multi-satellite maps. Unit: cm.

To infer the importance of this additional error, we have compared oceanic variability (F9) to a gross approximation of the additional error budget that is specific to Cryosat (F10) :

- By comparing ECMWF wet troposphere to the radiometer correction from ENVISAT
- By comparing GIM-based ionosphere to the dual frequency correction from Jason-2
- By using the formal error map of the gridded CNES/CLS MSS reference (non repeat orbit)



Cryosat's error is significant and even dominant except wherever mesoscale activity is very strong.

F10 : Quadratic sum of the ionosphere, wet troposphere and MSS error budgets used for Cryosat-2 in the mapping process. Expressed in cm RMS (top) and (bottom) in percentage of the oceanic variability map from Fig.9.

5 – Perspectives

There are two major perspectives to this successful demonstration:

1 - Exploitation of the SAR/doppler mode to cover high latitudes (e.g. Arctic) with 2 altimeters for the first time ever.

2 – Transition to operational NRT production (prototype processor ready and configured)

High quality L2 data (LRM+SAR) are needed